

# Surgical Anatomy of the Cervical Part of the Hypoglossal Nerve

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## Abstract

Iatrogenic injuries to cranial nerves, half of which affect the hypoglossal nerve, occur in up to 20% of surgical procedures involving the neck. The risk of injury could be minimized by in-depth knowledge of its positional and relational anatomy. Forty-one hypoglossal nerves were dissected from cadaveric specimens and positions described in relation to the internal carotid artery (ICA), external carotid artery (ECA), carotid bifurcation, mandible, hyoid bone, mastoid process, and the digastric tendon. The distance of the nerve from where it crossed the ICA and ECA to the carotid bifurcation was 29.93 ( $\pm 5.99$ ) mm and 15.19 ( $\pm 6.68$ ) mm, respectively. The point where it crossed the ICA was 12.24 ( $\pm 3.71$ ) mm superior to the greater horn of hyoid, 17.16 ( $\pm 4.40$ ) mm inferior to the angle of the mandible, and 39.08 ( $\pm 5.69$ ) mm from tip of the mastoid. The hypoglossal nerve loop was inferior to the digastric tendon in 73% of the cases. The hypoglossal nerves formed high loops in this study population. Caution should be exercised during surgical procedures in the neck. The study also revealed that the mastoid process is a reliable fixed landmark to locate the hypoglossal nerve.

## Keywords

- hypoglossal nerve
- landmarks
- iatrogenic
- injury

The extracranial part of the hypoglossal nerve (CN XII) emerges from the occipital bone of the skull via the hypoglossal canal in a plane medial to the carotid sheath.<sup>1</sup> This part is divided into vertical (descending), horizontal, and ascending segments. The vertical segment is located in relation to the internal and external carotid arteries. The horizontal segment forms a loop medial to the digastric tendon and the ascending segment ends by innervating the tongue musculature.<sup>1,2</sup> The position of the nerve in this region lends itself to iatrogenic injury during various surgical interventions in the upper neck.<sup>3</sup>

Cranial nerve injuries occur in up to 20% of cases during surgical procedures of the neck, majority of these involving CN XII.<sup>4</sup> One of the fundamental reasons for inadvertent injury is lack of visualization of the CN XII.<sup>5</sup> Conventional surgical landmarks used in the identification of the CN XII in the neck have not been consistently reliable.<sup>6</sup> These include the carotid bifurcation, occipital artery, sternocleidomastoid

artery, digastric tendon, the mandibular angle, as well as the hyoid bone.<sup>3,5,6</sup> For example, the CN XII nerve loop may variably lie superior, inferior, or at the same level as the digastric tendon.<sup>2,6,7</sup> Literature on use of bony landmarks is scanty despite the fact that these may offer less variable and hence dependable measurements.

This study aims to provide an account of the positional and relational anatomy of the cervical part of the hypoglossal nerve, which will be used by surgeons working in this area. This is following an increase in penetrative and crash injuries as well as neoplastic lesions involving the neck and floor of the mouth.<sup>8–10</sup> Incapacitating effects of iatrogenic CNXII injury such as dysphagia and dysarthria may then be minimized.<sup>11–13</sup>

## Materials and Methods

Forty-one head and neck hemi sections from formalin-fixed cadavers of black African decent were obtained from the

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Department of Human Anatomy, University of Nairobi, and studied for the positional and relational anatomy of the CNXII. The cadavers were of adult age group ranging from 25 to 55 years and were embalmed within 24 hours after death by perfusion of 10% formal saline through the femoral vessels. Dissection and measurements for the study were done within 1 month of preservation.

### Exposure

The hemi sections were dissected by making a descending linear skin incision from the base of the mastoid process extending in two directions: caudally along the anterior border of the sternocleidomastoid muscle (SCM) and another on the inferior border along the body of the mandible exposing the submandibular region. The triangular skin flap, platysma, external jugular vein, and SCM were reflected inferiorly to expose the digastric bellies and tendon. The carotid sheath was displayed deep to the posterior belly of digastric muscle and the internal jugular vein (IJV) was severed to expose the common, internal, and external carotid arteries. These were carefully dissected out to show the position of the CNXII as it crossed the vessels. At this point, the superior root of ansa cervicalis was also identified connected to the CN XII and its inferior course noted. The greater horn of the hyoid was then palpated and the CN XII identified superior to it. The nerve was dissected out deep to the body of the mandible to the point where it terminated into the musculature of the tongue.

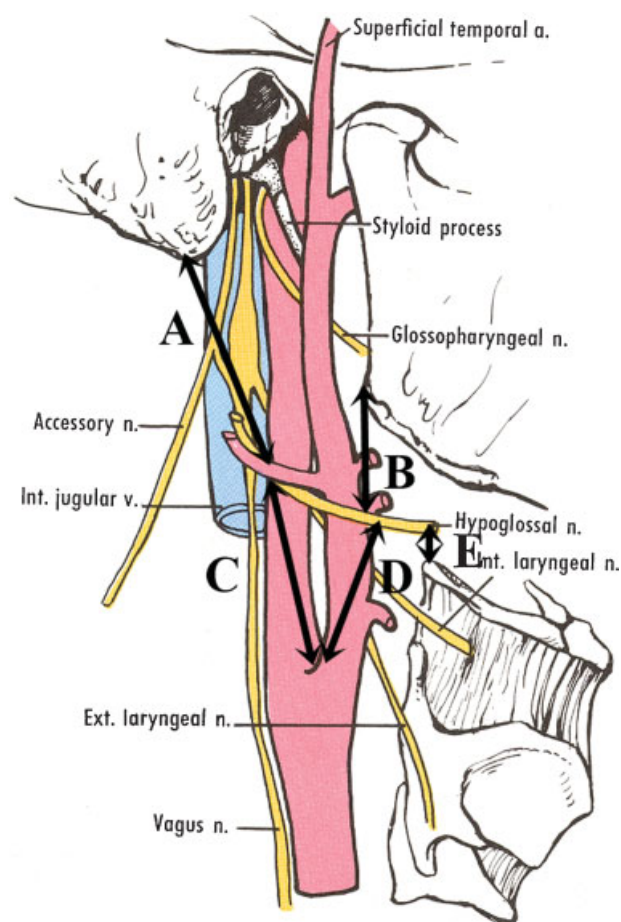
### Determining the Position to the Landmarks

The cadaver was placed in the supine position with the head lying in the Frankfurt horizontal plane.<sup>14</sup> The position of the CN XII in relation to tip of the mastoid, mandibular angle, carotid bifurcation, and greater horn of hyoid was noted (►Fig. 1). In relation to the point where the nerve crossed the internal carotid artery (ICA) and external carotid artery (ECA), for the former the proximal crossing point has been considered and for the latter the distal crossing point has been considered.

These measurements were made considering the level of bifurcation of the common carotid artery which was recorded to be high when it was superior to the upper border of the thyroid cartilage (type I), at the same level (type II) or inferior to it (type III).<sup>15</sup> The relation of the loop of the CN XII to the digastric tendon was also observed and recorded. It was classified as superior, at the same level, or inferior to the digastric tendon as depicted in ►Fig. 2.

### Data Analysis and Presentation

Raw data were collected using data sheets and then tabulated and analyzed using statistical package for social sciences (SPSS) version 21 (SPSS IBM, New York). Distances from various landmarks were expressed as means and standard deviations. The statistically significant differences between the side measurements were determined using the paired Student's *t*-test; *p*-value of  $\leq 0.05$  was considered to be statistically significant. Data were presented using tables and photographs.



**Fig. 1** Position of the CN XII. The distances: (a) CN XII to tip of mastoid, (b) CN XII to angle of mandible, (c) CN XII from point crossing ICA to carotid body, (d) CN XII from point crossing external carotid artery to carotid body, and (e) CN XII to greater horn of hyoid bone.

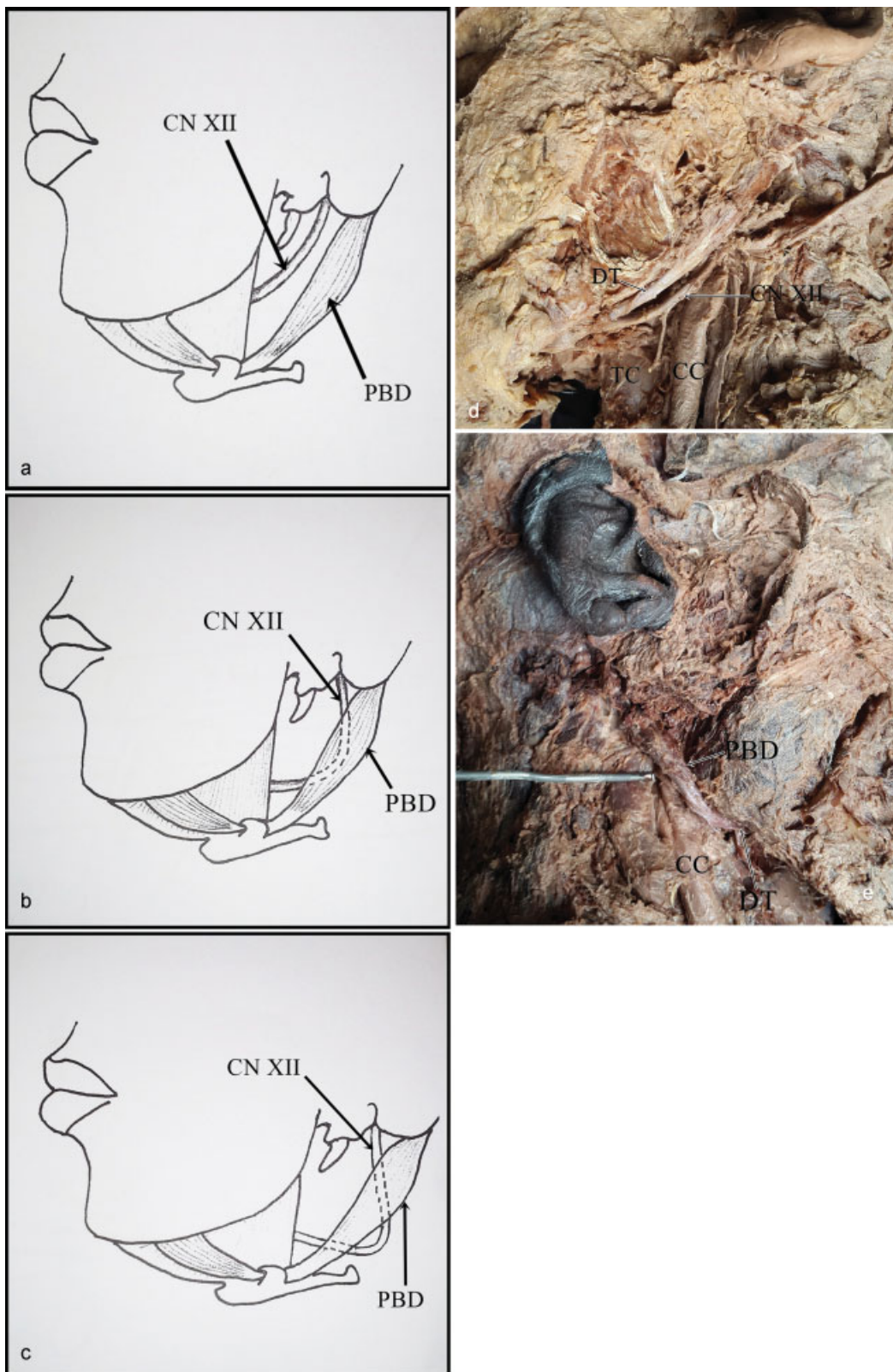
### Results

The cervical part of CN XII was identified in all 41 hemi sections dissected, in a plane deep to the IJV and superficial to the internal and external carotid arteries. The vertical segment of the CNXII nerve crossed the ICA and ECA at a level superior to the carotid bifurcation in the majority (88%) of the cases while the rest lay on the carotid bifurcation (►Fig. 3).

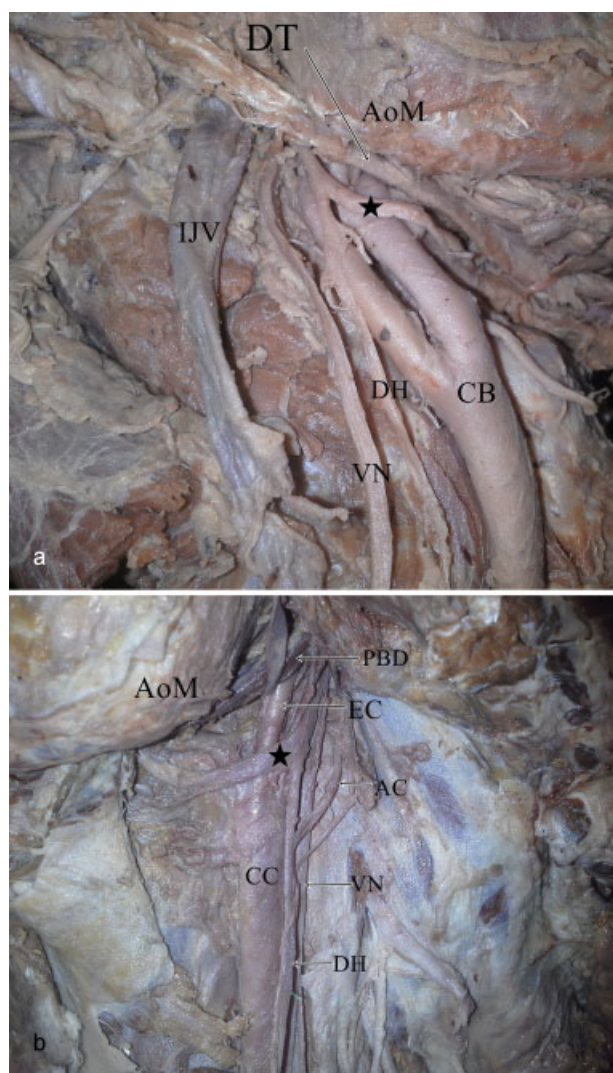
#### Position of the CN XII

The CN XII crossed the ICA and ECA at a point 29.93 ( $\pm 5.99$ ) mm and 15.19 ( $\pm 6.68$ ) mm from the carotid bifurcation, respectively. The ICA and ECA crossing point for the left CN XII was 30.22 and 14.08 mm while that for the right CN XII was 28.69 and 16.31 mm, respectively.

The CN XII nerve was located 12.24 ( $\pm 3.71$ ) mm superior to the greater horn of hyoid and 17.16 ( $\pm 4.40$ ) mm inferior to the angle of the mandible. The distances were 12.72 and 16.68 mm for the left CN XII and 11.84 and 17.58 mm for the right CN XII, respectively. The distance from the point the nerve crossed the ICA to the tip of the mastoid was 39.08 ( $\pm 5.69$ ) mm, and it was 38.35 for the left CN XII and 39.71 mm for the CN XII, respectively. The difference in



**Fig. 2** Relation of the CN XII loop to the digastric tendon. (a) CN XII loop superior to the digastric tendon. (b) CN XII loop at the same level as the digastric tendon. (c) CN XII loop inferior to the digastric tendon. (d) Dissected cadaveric specimen on the left side showing the CN XII nerve looping below the digastric tendon (DT). (e) Dissected cadaveric specimen on the right side showing the CN XII nerve (probed) coursing along the posterior belly of digastric muscle (PBD) to lie at the same level as the DT. CC, common carotid artery; TC, thyroid cartilage.



**Fig. 3** Relation of the CN XII loop to the carotid bifurcation. (a) Dissected cadaveric specimen on the right side showing the CN XII nerve (star) forming a high loop by crossing high above the carotid bifurcation (CB). The loop is also below the digastric tendon (DT). (b) Dissected cadaveric specimen on the left side showing the CN XII nerve (star) coursing on the carotid bifurcation. The CN XII loop is also below the posterior belly of digastric muscle (PBD). AC, ansa cervicalis; AoM, angle of mandible; CC, common carotid artery; ECA, external carotid artery; IJV, internal jugular vein; DH, descendens hypoglossi; VN, vagus nerve.

distance between the right and left sides was not statistically significant (► **Table 1**). However, the right CN XII appeared to be positioned further superiorly from the carotid bifurcation as it crossed the ECA.

A type I (high) bifurcation of the common carotid artery (CCA) was noted in 31 (75.6%), where the bifurcation was above the superior border of the thyroid cartilage while 9 (22.0%) were at the same level as the superior border of the thyroid (type II) and 1 (2.4%) was inferior to it (type III) (► **Fig. 4**). There was no statistically significant difference observed between the distances to the different landmarks based on the levels of carotid artery bifurcation (► **Table 2**). However, the distance from the tip of the mastoid to the CN XII increased notably with lower levels of carotid bifurcation.

### Relation to Digastric Tendon

The CN XII was a medial relation of the digastric tendon in all the 41 dissected specimens. The nerve formed a loop as it altered its course from the vertical to the horizontal segment. This loop showed varying relation to the digastric tendon. In 11 (26.8%) of the specimens, the CN XII was positioned at the same level as the digastric tendon while all the rest formed a loop that was inferior to the tendon. The distance ranged from 4 to 16 mm inferior to the digastric tendon (► **Fig. 2**).

### Discussion

With increase in penetrative and crash injuries as well as neoplastic lesions involving the neck and floor of the mouth, surgical manipulation of the upper neck has become more common.<sup>8–10</sup> As a result, there has been an upsurge in the cases of inadvertent injury to structures in this region. The hypoglossal nerve, which is often involved in more than 20% of the procedures,<sup>4</sup> results in incapacitating effects of impaired speech and feeding.<sup>11,13</sup>

### Position of the CN XII

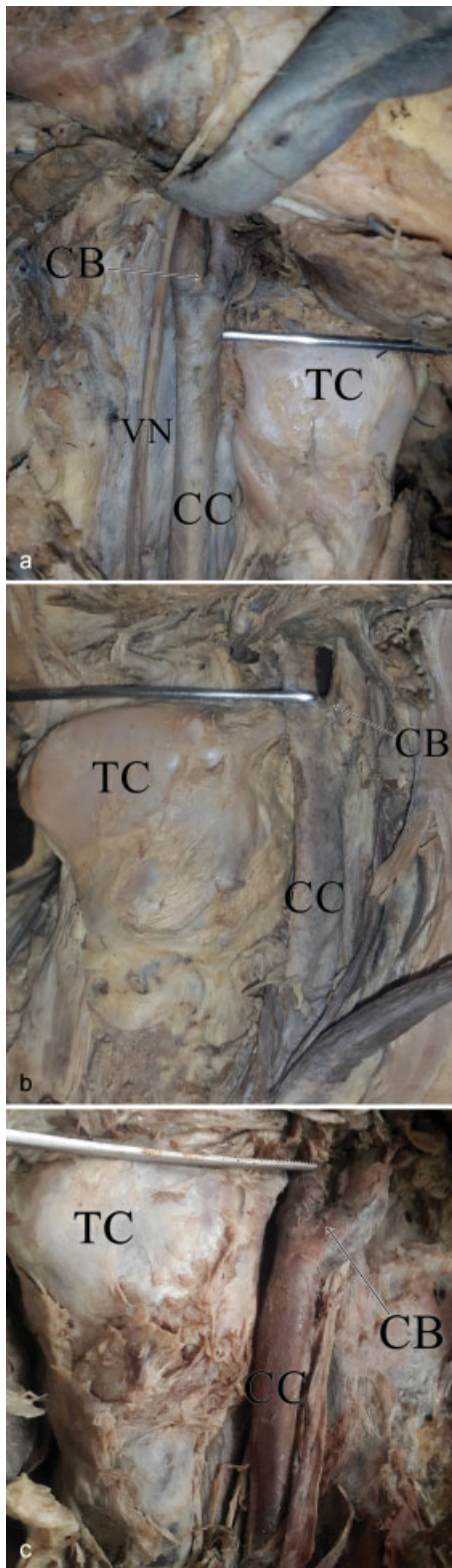
The CN XII was identified in all specimens dissected. There was no statistically significant difference in the distances obtained from the left and right side, not reported previously. Neither was there a significant difference when the different levels of carotid bifurcations were considered.

**Table 1** Position of CN XII in relation to landmarks

Landmark	Mean distance left, mm (±SD)	Mean distance right, mm (±SD)	p-Values
Carotid bifurcation as it crosses ICA	30.22 (±5.38)	29.69 (±6.60)	0.78
Carotid bifurcation as it crosses ECA	14.08 (±5.89)	16.31 (±7.38)	0.33
Greater horn of hyoid	12.72 (±3.50)	11.84 (±3.92)	0.46
Tip of mastoid process	38.35 (±4.81)	39.71 (±6.39)	0.45
Angle of mandible	16.68 (±3.71)	17.58 (±4.97)	0.52

Abbreviations: ECA, external carotid artery; ICA, internal carotid artery; SD, standard deviation.

Notes: The position of the CN XII on the left and right sides in relation to the carotid bifurcation, greater horn of hyoid, tip of mastoid process, and angle of mandible. The table shows the mean distance, the standard deviation, and the p-values.



**Fig. 4** Types of common carotid artery (CCA) bifurcation. (a) Dissected cadaveric specimen on the right side showing a high level (type I) of carotid bifurcation (CB). The upper boarder of the thyroid cartilage (probed) is below the level of the level of bifurcation. (b) Dissected cadaveric specimen on the left side showing the carotid bifurcation (CB) at the same level (type II) as the upper boarder of the thyroid cartilage (TC). (c) Dissected cadaveric specimen on the left side showing the carotid bifurcation (CB) positioned lower (type III) than the upper boarder of the thyroid cartilage (TC).

This article reports that the distance from the CN XII at the point it crossed the ECA to the carotid bifurcation on average was 15 mm. This finding is in agreement with previous reports.<sup>6,16</sup> However, the average distance from the CN XII at the point it crossed the ICA to the carotid bifurcation was observed to be greater (30 mm) in the study population as compared with reports by other authors working on different populations (–Table 3). This implies that most of the CN XIIs studied formed a high loop. Additionally, the CN XII was 12 mm superior to the greater horn of hyoid and 17 mm inferior to the mandibular angle. These results differed from reports by Salame and colleagues who examined specimen from an Israeli population. They reported the distance on average from the nerve to mandible and hyoid bone to be 25 and 9 mm, respectively.<sup>3</sup> It is, however, worth noting that the study by Salame et al did not state the specific points of the hyoid and the mandible used. This might suggest that the points of reference were not the same and hence the observed difference.

The distance from the CN XII at the point where it crossed the ICA to the tip of the mastoid process was 40 mm. The use of the tip of the mastoid as a landmark used to locate the CN XII has hitherto not been described in the available literature. However, the tip of the mastoid may serve as a reliable landmark to locate the CN XII. From the studied population, the measurement showed minimal variation. This may be owed to its fixed position and prominence which allows easy identification. Most studies reported soft-tissue landmarks such as carotid bifurcation,<sup>3,16</sup> occipital artery,<sup>2</sup> and sternocleidomastoid artery.<sup>6</sup> However, these landmarks exhibited great variability. This article reports mean distances from the carotid bifurcation to the CN XII as it crosses the ICA and ECA to be 20.5 to 43 and 6 to 32 mm, respectively, while Kim et al reported average distances of 3.9 to 37.0 and 2.6 to 29.4 mm, respectively.<sup>6</sup> These findings demonstrate the great variability of the measurements obtained from the soft-tissue landmarks. However, the bony landmarks employed in this study yielded less variable measurements and hence may serve as more reliable indicators of the CN XII position.

The distance from the CN XII as it crossed the ICA to the carotid bifurcation was noted to differ with reports from other studies. In this article, the distance was ~approximately 30 mm as compared with 18 and 21 mm reported by workers who sampled a Korean population.<sup>6,16</sup> The variation observed may most likely to be due to population differences. This is supported by the fact that the preparation method (embalming using formaldehyde) for specimen used in all the studies is similar. In addition, the age and gender characteristics are comparable.

Voskanian et al reported that a high loop of the ICA is a statistically and clinically significant risk factor for CN XII injury.<sup>5</sup> It is therefore important for surgeons in the population studied to be cognizant of this to avoid injury to the nerve in procedures involving surgical exposure and manipulation of the ICA and ECA.

**Table 2** Position of CN XII in relation to type of carotid bifurcation

Landmark	Mean distance type I, mm ( $\pm$ SD)	Mean distance type II, mm ( $\pm$ SD)	Mean distance type III, mm ( $\pm$ SD)	p-Values
Carotid bifurcation as it crosses ICA	30.03 ( $\pm$ 5.75)	30.04 ( $\pm$ 7.32)	26.00	0.81
Carotid bifurcation as it crosses ECA	14.37 ( $\pm$ 5.25)	17.611 ( $\pm$ 10.00)	15.00	0.47
Greater horn of hyoid	12.17 ( $\pm$ 3.58)	13.07 ( $\pm$ 4.05)	7.00	0.30
Tip of mastoid process	38.34 ( $\pm$ 5.08)	42.40 ( $\pm$ 6.63)	32.00	0.07
Angle of mandible	16.532 ( $\pm$ 4.59)	19.12 ( $\pm$ 3.43)	19.00	0.28

Abbreviations: CCA, common carotid artery; ECA, external carotid artery; ICA, internal carotid artery; SD, standard deviation.

Notes: The position of the CN XII in relation to the carotid bifurcation, greater horn of hyoid, tip of mastoid process, and angle of mandible in different levels of CCA bifurcation. The table shows the mean distance, the standard deviation, and the p-values.

**Table 3** Comparison of CN XII position in different populations

Study	population	Carotid bifurcation as it crosses ICA	Carotid bifurcation as it crosses ECA	Greater horn of hyoid	Tip of mastoid process	Angle of mandible
Salame et al 2006 (n = 46)	Israel	14.69 $\pm$ 6 0.58 <sup>a</sup>		9.76 $\pm$ 3.4 <sup>b</sup>	–	24.65 $\pm$ 5.47 <sup>b</sup>
Kim et al 2009 (n = 30)	Korean	20.95 $\pm$ 7.78	15.33 $\pm$ 7.86	–	–	–
Shin et al 2012 (n = 29)	Korean	18.5 $\pm$ 6.7	15.1 $\pm$ 5.70	–	–	–
Present study (n = 41)	Kenyan	29.93 $\pm$ 5.99	15.19 $\pm$ 6.68	12.24 $\pm$ 3.71	39.08 $\pm$ 5.69	17.16 $\pm$ 4.40

Abbreviations: ECA, external carotid artery; ICA, internal carotid artery.

Notes: Comparison of the mean distance of the CN XII in different populations in relation to the carotid bifurcation, greater horn of hyoid, tip of mastoid process, and the angle of the mandible.

<sup>a</sup>The average distance from the carotid bifurcation to the CN XII. This measurement does not take into account the different points on the CN XII as it crosses the ICA and ECA.

<sup>b</sup>The specific points on the hyoid bone and mandible not stated.

**Table 4** Relation of CN XII to digastric tendon in different populations

Study	Population	Superior to digastric tendon	Same level as digastric tendon	Inferior to digastric tendon
Salame et al 2006 (n = 46)	Israel	46%	54%	
Bademci and Yaşargil 2006 (n = 20)	Turkish	–	–	100%
Homze et al 1997 (n = 91)	American	58%	–	42%
Present study (n = 41)	Kenyan	–	27%	73%

Note: Comparison of the proportions of CN XII related to superior, inferior, or at the same level as the digastric tendon in different populations.

### Relation to the Digastric Tendon

The CN XII loop was located inferior to the digastric tendon in 73% of the cases and was at same level as the tendon in the rest of the cases. These findings differ with reports in other populations. Homze et al reported more than half (58%) of the cases in an American population to be superior to the digastric tendon while the rest of the cases were inferior to it.<sup>17</sup> These findings are in agreement with those made by Salame et al, in an Israeli population where 46% were superior to the tendon and the rest of the CN XII loops were located inferior to the digastric tendon.<sup>3</sup> Contrary to the

findings from the current study and studies from the Israeli and American populations, Bademci and Yaşargil found that CN XII loops that were dissected in a Turkish population were located inferior to the digastric tendon<sup>2</sup> (► **Table 4**). These results suggest population differences.

This article reports that nearly 25% of the CN XII loops were located deep to or at the same level as the digastric tendon. This should be considered in carotid endarterectomy, where the arterial plaque extends distally and splitting of the posterior belly of digastric muscle may be necessary to free the CN XII.<sup>18</sup>

## Conclusion

The majority of the hypoglossal nerves in the population studied formed high loops which are known to be associated with a high incidence of iatrogenic injury. Therefore, it is recommended that caution be exercised during surgical procedures in the neck. The study also revealed that the mastoid process is a reliable fixed landmark to locate the hypoglossal nerve.

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